

# THE WILSON BULLETIN

A QUARTERLY MAGAZINE OF ORNITHOLOGY

*Published by the Wilson Ornithological Society*

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VOL. 88, No. 3

SEPTEMBER 1976

PAGES 377-528

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## ROSEATE TERN BILL COLOR CHANGE IN RELATION TO NESTING STATUS AND FOOD SUPPLY

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In a previous paper (Donaldson 1968) I described the change in bill color of Roseate Terns (*Sterna dougallii*) breeding on Great Gull Island, New York, (41°12' N. Lat., 72°07' W. Long.), at the eastern end of Long Island Sound. Briefly, when the Roseates arrive at the island in early May the bill is all black. During incubation red appears at the base of the bill. The extent of red increases until about the time the young fledge. At the end of the season the bill becomes all black again.

At the time of the 1968 paper, data were not available on the exact nesting status of most of the birds measured, and it had not been possible to follow the bill color change of individual Roseates. These data, and more, are now available.

In this paper I describe the bill color change of a marked pair of Roseate Terns followed from the time the first red began to appear during incubation through the time their young fledged. I compare the average of measurements of the extent of red on the bills of Roseate Terns trapped on Great Gull Island for 1968-1970, 1972, and 1974 and discuss these figures in relation to estimates of food available. I also present the bill color measurement data in relation to sex, weight, clutch size, and age. Finally, I discuss some data on bill color of Roseates in the Caribbean and speculate on the possible adaptive significance of bill color change in the Roseate Tern in light of the unique timing of this change.

### METHODS

The pair of adult Roseate Terns illustrated in Plates 1 and 2 had been individually color-marked 21 June 1969 as part of our program of color-banding adult terns (Hays 1970b). The sexes of the pair were determined by H. Hays in late August 1972 when she observed one bird (USFWS 742-75155) mount the other (USFWS 742-75165). I refer to the former as M for male and the latter as F for female. This sexing was

consistent with observations in 1974 of their display behavior and their roles in incubation and feeding the young.

In 1971 and 1974 M and F nested in the grass at the top edge of a 4m high retaining wall opposite a tower from which they were observed and photographed. In 1971 I photographed this pair daily from 15 June–11 July, when they moved their young into the rocks below the tower. We then set up a blind near where they fed their young and I photographed them 18 July–14 August. This 1971 series showed no detectable difference in extent of red from day to day. Comparison of photographs taken at 3- and 4-day intervals did show a perceptible change. In 1974 Joan Black photographed M and F on 8 June. My husband and I then photographed them twice a week from 22 June through 18 July, and on 25 June I photographed M held in the hand.

In both years M and F were photographed through the last day they were seen on the island, and all photos both years were taken between 11:00 and 13:00. The slides from 1974 were sharper than those from 1971. The plates are based on the 1974 slides except for the figure of F on 14 August 1971.

J. Black photographed with a Nikon F2 camera body and 500 mm reflex lens. All other photos were taken with a Konika FP camera body with a 450 mm Soligor lens. In 1971 Kodachrome II film was used. In 1974 high speed Ektachrome was used for all photos except those taken 8 June, when Ektachrome X was used. I have included the 8 June 1974 and 14 August 1971 pictures in the plates, although they were taken with different films, because they show the extremes early and late in the change. In the 8 June slide the bills are almost completely black with only a trace of red at the base. The 14 August picture shows the faded red of the bill late in the season. That this color is not an artifact of the difference in film type is demonstrated by comparison of leg color (which does not change during this period); the legs appear identical in slides made with the 3 film types. Use of the Kodachrome II slide was further validated by comparisons of slides of the same birds taken in 1971 on Kodachrome II and in 1974 on high speed Ektachrome.

Referring to the slides for each date, Kathleen Duffin painted the tern heads using the guache technique with Guitar brand watercolors. In the case of the figures for the female on 8 and 18 July, the *extent* of red is as shown for these dates, but the *shade* of red is that of the slides from 5 and 15 July respectively, as the slides of her from 8 and 18 July were overexposed.

In 1968–1970, 1972, and 1974 I measured the extent of red on the bills of 872 Roseate Terns trapped on nests that had been numbered when the first egg was laid. Using dial calipers I measured to the nearest mm the red on the side of the upper mandible along a line from the edge of the feathering to the tip of the bill, passing along the line of the nostril. I use gross measurements rather than a percentage of red because the variation in distance from the base of the feathers to the distal end of the nares among Roseates is negligible (Donaldson 1968). As I measured adults only at the time their eggs hatched, the red on the bill rarely extended beyond the distal end of the nares.

I have compared the measured extent of red on the bills of the Roseates we trapped during the first part of each nesting season for all years (Table 3). The varying calendar dates of these periods reflect differences in the timing of first eggs and of the peak dates of newly established Roseate nests. The nesting status of the birds trapped in each of these periods was directly comparable. All adults were trapped on

newly hatched or 1-day-old chicks and the measurements of those birds trapped on the first nest to hatch each year are compared.

The 1972 season was exceptional. On 22 June 1972 Hurricane Agnes destroyed many nests; birds subsequently re-nested, so that there were more birds nesting late than in any other year of the study. We were able to continue trapping Roseates in August. I have, therefore, grouped the birds trapped after 7 July 1972 into a second and third period for that year: 8-22 July, and 23 July-1 August.

In 1970 and 1972 I weighed the birds to the nearest gram using a Pesola balance. In 1974 I weighed them to the nearest tenth of a gram on a triple beam balance.

#### RESULTS

Plates 1 and 2 show the bill color change of a pair of Roseate Terns from the middle of incubation to about 6 weeks after the young have hatched. I have notes on this pair taken 2 June, 6 days before the first picture in Plate 1 and 18 days before the first egg hatched: I describe M as having the bill completely black on both sides, and F as having a trace of red at the base on the right side with no red on the left.

Table 1 represents an expanded legend for Plates 1 and 2. The side of the bill actually illustrated in the plate is discussed first, then the opposite side if it was different.

In 1974 we did not see M and F after their second chick flew on 18 July. In 1971 they were seen through 14 August, thus allowing me to photograph the faded bill of F. The first slide from 1971 that shows fading of the red is that of F on 2 August. The red continued to fade as is shown in the slides for 7 August, yet between 27 July and 7 August in 1971 the extent of red on F's lower mandible increased to the amount shown for her on 14 August (Plate 2). The slide record of M's fading bill is not so complete as that of F, but his bill appears to have reached its maximum brightness about 27 July also, and was beginning to fade on 9 August.

In both 1971 and 1974 the extent of red on the female's bill was consistently greater than that of the male. It appears likely that there is no consistent sexual dimorphism in bill color, as in 10 of the 235 pairs trapped and measured, there was no difference in extent of red on the bills of mates (Table 2).

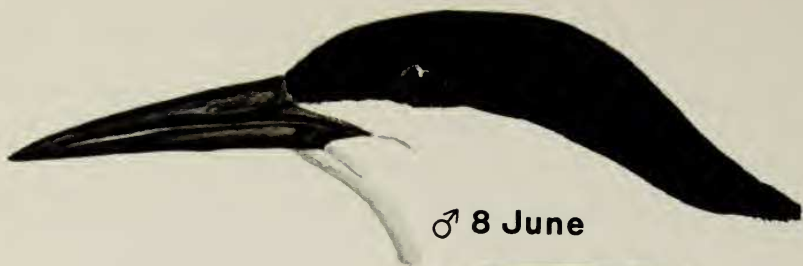
The acquisition of red for most Roseate Terns in the Great Gull Island colony appears to follow the pattern shown for M and F, the first red appearing at the base of the bill during incubation (Donaldson 1968). In 1969 I noted a single exception to this pattern. On 16 May I picked up a freshly dead Roseate Tern with 2 mm of red at the base of the bill. This bird had several developing ova, but no ruptured follicles. The first Roseate egg marked on Gull Island in 1969 was found on 21 May, 5 days later. The 15 May bird beginning to show red was thus exceptionally advanced.

TABLE 1  
LEGEND FOR PLATES 1 AND 2

Date	Nest Status	Ind.	Side	Description
6/ 8/74	12 days before hatching	M	L	LM*trace of dark red
		F	L	LM dark red coming in on lower part. UM** red extending down from base of culmen to distal end of nares.
6/25/74	chicks 3 and 5 days old	M	R	LM, red extending less than on side of UM, where it reaches beyond nares.
			L	No slide
		F		No slides
7/ 1/74	chicks 9 and 11 days old	F	L	Red now solidly filled in at base of bill and much increased in extent and brightness since 8 June.
			R	Same as left side, but with a light diffused red over the nares on culmen.
		M	L	Extent similar to that on 25 June, but red brighter.
7/ 8/74	chicks 16 and 18 days old	F	L	Red brightened and extended in last week, especially along culmen.
			R	Red extends 2mm farther beyond nares and 3mm more along cutting edge of LM, than on left side. This was the greatest difference between the sides for any date for either bird.
		M	L	Red brightened and filled in at base since 1 July, and extends somewhat farther along culmen.
7/18/74	chicks 26 and 28 days old (The elder had flown from the wall. The younger flew 18 July.)	F	L	Bright red extending along almost 50% of the side (i.e. from the point where the black and white feathers meet with the UM, to the distal point of red).
		M	L	Red extending along about 40% of the side of the upper mandible.
			R	No slide.
8/14/74	chicks 41 and 44 days old	F	L	Red is very faded, diffused with black and there is a definite area of black at the base of the UM.

\* LM = lower mandible  
\*\* UM = upper mandible





♂ 8 June



♀ 8 June



♂ 25 June



♀ 1 July



♂ 1 July



♀ 8 July



♂ 8 July



♀ 18 July



♂ 18 July



♀ 14 Aug.

KED 1975





TABLE 2  
DIFFERENCE (MM) OF RED ON RIGHT SIDE, BETWEEN MEMBERS  
OF PAIRS TRAPPED WITHIN ONE DAY OF EACH OTHER

Difference	Number of Birds						1974
	1968	1969	1970	1972	1972*	1972**	
0	2	4	2				2
.1-1.0	4	12	15	6	8	13	10
1.1-2.0	8	17	9	6	7	10	7
2.1-3.0	4	8	7	2	5	6	9
3.1-4.0	3	5	3	1		3	3
4.1-5.0	1	4			2		3
5.1-6.0		3			4	1	1
6.1-7.0		1			2		1
7.1-8.0		1			3	2	
8.1-9.0						1	
9.1-10.0		1					1
11.1-12.0							2
12.1-13.0		1					

\* Second period of 1972.

\*\* Third period of 1972.

All other dates are for the first trapping periods, as detailed in the methods section.

TABLE 3  
RED ON THE BILLS OF ROSEATE TERNS IN DIFFERENT YEARS<sup>1</sup>

Dates	No. of terns	Mean	S. D.	Range
14 June-3 July 1968	30	4.47	2.26	0-11.4
14 June-4 July 1969	115	6.24	2.53	0-17.4
15 June-5 July 1970	63	5.57	1.80	0-10.0
24 June-7 July 1972	84	5.56	3.07	0-15.4
22 June-5 July 1974	89	6.65	2.86	0-18.3

Significance of difference in means of extent of red between years:

	Value of t	P =
1968 vs. 1969	3.462	.01
1968 vs. 1970	2.502	.02
1968 vs. 1972	1.764	.1
1968 vs. 1974	3.763	.01
1969 vs. 1970	1.849	.1
1969 vs. 1972	1.701	.1
1969 vs. 1974	1.079	.3
1970 vs. 1972	0.024	.5
1970 vs. 1974	2.263	.05
1972 vs. 1974	2.404	.02

<sup>1</sup> Measurements (mm) of red on the side of the bill of birds whose first chick was newly hatched or one day old.

TABLE 4  
WEIGHTS (G) OF ADULT ROSEATE TERNS

Dates	Number	Mean	S. D.	Range
15 June-5 July 1970	144	109.8	6.8	96-128
24 June-7 July 1972	72	107.9	6.4	96-120
22 June-7 July 1974	83	112.6	7.3	98-133

Table 3 compares the measurements of the extent of red on the bills of Roseate Terns trapped in all years. Comparison of the means for like periods shows significant differences: the 1974 mean is greatest (i.e. the bills had the greatest extent of red), followed closely by 1969, then by 1972 and 1970 which are very similar; 1968 is lowest. Individual Roseates remeasured in succeeding years (Fig. 1) tend to bear out the pattern of annual differences shown for the total sample in Table 3.

These differences in the extent of red from year to year coincide with apparent differences in the fish supply. For instance, in 1968, when the extent of red on the Roseates' bills was low, there was a scarcity of fish in the colony (Hays 1970a; LeCroy and Collins 1972). In 1969 and 1974, when the average extent of red was much greater, there were apparently more fish (LeCroy and LeCroy 1974; pers. observ.).

I found some correlation between weight and bill color, with heavier Roseates tending to have a greater extent of red on the bill. I compared the average weight of birds with 0-10 mm red with that of birds with 10-20 mm of red. The group with less red averaged lighter in weight, although the difference was not statistically significant.

There was a significant ( $P = .05$ ) difference between the mean of the weights for 1974 and the mean of the weights for both 1970 and 1972 (Table 4). This pattern, with 1970 and 1972 similar and 1974 higher, is the same as the yearly pattern for extent of red on the bills. Both the weight and the bill color differences thus appear to reflect differences in food supply from year to year.

I found no consistent relationship between clutch size and bill color. In 1968, 1969, and 1974, birds on 1-egg clutches averaged slightly redder bills than birds on 2-egg clutches, but the differences were not statistically significant. In 1970 and all 3 periods of 1972, birds on 2-egg clutches had more red than did those on 1-egg clutches, but the difference approaches significance only for the last period of 1972.

Within the large samples of birds measured each year, there was considerable individual variation in the extent of red on the bills of birds of the same nest status. For instance, in 1972 (Fig. 2), some Roseates had

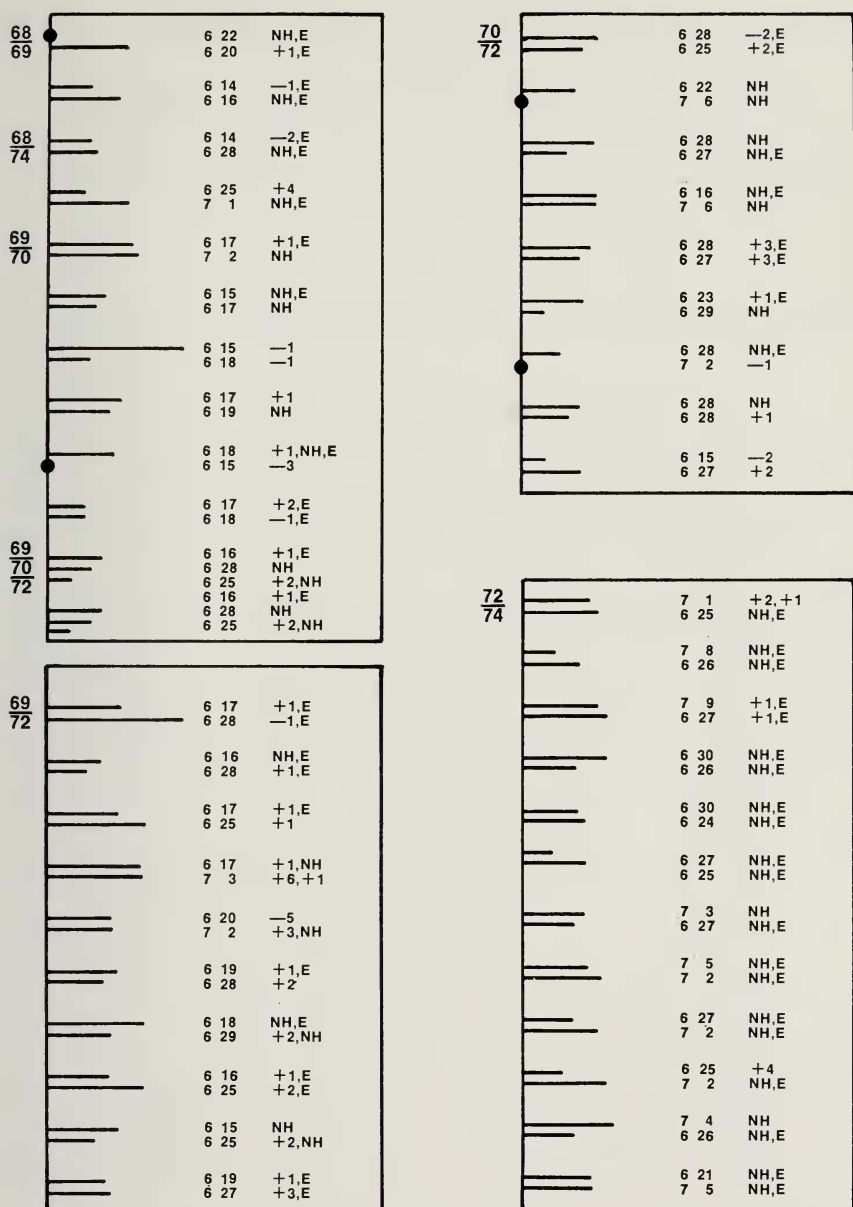


FIG. 1. Each grouping of lines represents the extent of red on the bill of an individual Roseate measured in more than 1 year, e.g. (19)68/(19)69, followed by the date on which it was measured each year and its nest status at the time of measurement. NH = newly hatched chick, E = egg, -5 to +4 = days before (-) or after (+) hatching.

TABLE 5  
RANGES OF RED ON THE BILLS OF KNOWN AGE BIRDS WHOSE FIRST CHICK  
WAS NEWLY HATCHED OR ONE DAY OLD

Age in years	Extent of red (mm) <sup>1</sup>	No. of birds
2	1.5-17.0	3
3	2.5-14.5	13
4	3.4- 8.0	7
5	3.0-14.5	8

<sup>1</sup>These ranges are a summary taken from all years trapping was done (1968-1970, 1972, and 1974).

more than 10 mm of red in June while others had none. There was a marked increase in the number of birds having more than 10 mm of red that were trapped on new chicks late in the 1972 season (Fig. 2). It may be that these were birds that had first nested during June and their bills had already started to become red before the hurricane destroyed their nests.

Even birds of the same age, all measured at the time their first young hatched, varied in the extent of red on their bills (Table 5). Most of these known age birds were trapped in 1972, and are shown individually in Fig. 2, where their ages are indicated by the numeral next to their symbol. The two-year-olds are of particular interest. In addition to the one shown in Fig. 2, I have data on 3 two-year-olds from other years. One, trapped on a nest of unknown age 23 June 1967, had 1 mm of red on its culmen. Another, trapped over a 1-day-old chick, measured 17 mm of red on 3 August 1971 (Donaldson 1971). The third, also trapped 3 August 1971, one day before its chick hatched, had 17 mm red.

Roseate Terns in other parts of the world may differ from the Gull Island birds in the timing and rate of acquisition of red on their bills. Between 22 and 26 May 1968, Helen Hays and I surveyed 275 Roseate Terns on small islands off St. Thomas in the Virgin Islands. Thirty of these Roseates had all black bills. The rest had amounts of red on the bill varying from a few millimeters to  $\frac{2}{3}$  of the bill red. These birds were standing along the shores of the islands. The islanders are permitted to collect eggs of sea-birds until the end of May, and as our search of 4 islands where the birds breed yielded only 6 nests, it seemed likely that the first clutches of most of the birds we saw had been collected.

We aged the eggs by flotation (Hays and LeCroy 1971) in the 6 nests we found, and all but one, which had been incubated 1 or 2 days, were fresh. I trapped an adult on a fresh egg 22 May and the measured red on its culmen was 8.7 mm. These measurements are comparable in extent

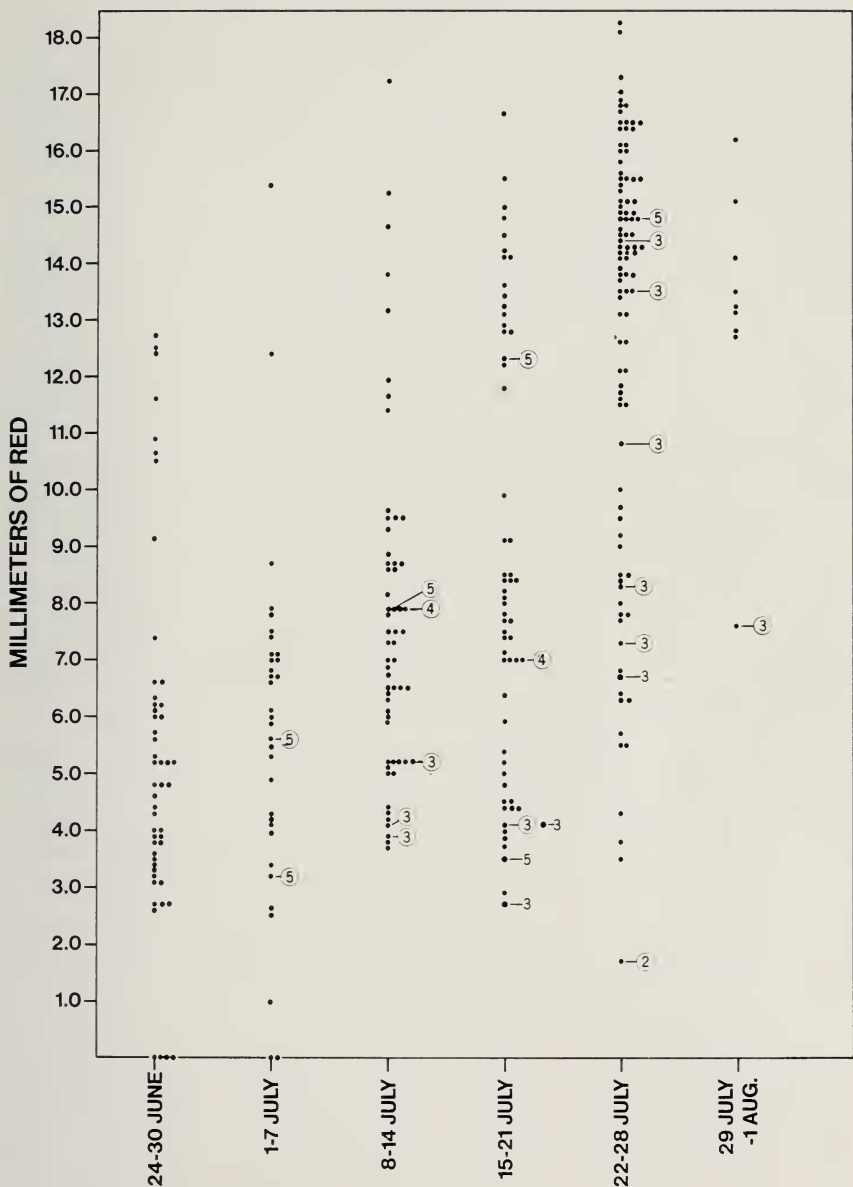


FIG. 2. Each Roseate Tern measured in 1972 is represented by a dot indicating the extent of red on its bill. The numerals indicate the age of known-age birds. Numerals without circles are known-age birds trapped over chicks 2-4 days old. All other birds were trapped when their first chick was newly hatched or one day old.